International Journal of Economic Practices and Theories (IJEPT)
ISSN: 2247-7225
Volume 2026, Issue 1

Food Packaging in the Circular Economy: A System-Level Review of Sustainability, Food Safety and Consumer Behaviour.

[1]Gayathri Balachandran, [2]Dr. Pritha Chaturvedi

[1]PhD Scholar, Faculty of Management Studies, ICFAI University, Jharkhand

E-Mail Id -gayathrib2006@gmail.com

[2]Assistant Professor, Faculty of Management Studies, ICFAI University, Jharkhand,

E-Mail Id –prithachaturvedi@iujharkhand.edu.in

Abstract

Food packaging is a basic but important part of the modern food system. It protects food from physical, chemical and microbiological hazards, makes storage and transport easier, helps maintain shelf life, provides product information and offers convenience to consumers. At the same time, the largely linear way in which packaging is produced, used and discarded has increased the use of virgin resources and contributed to packaging waste, pollution and challenges in managing materials that are often used for only a short time. The circular economy (CE) offers a different way of thinking about this system, with greater emphasis on resource efficiency, waste prevention, reuse, recovery and keeping products and materials in use for as long as practical. For food packaging, however, circularity cannot be judged simply by whether a package is recyclable, reusable, biodegradable or made from renewable resources. The package must still protect the food, meet food-contact safety requirements, keep environmental burdens as low as possible, be economically workable and fit the collection and waste-management systems available to consumers.

This critical review brings together evidence on circular food packaging across environmental sustainability, food safety, chemical migration, consumer behaviour, life-cycle assessment (LCA), reuse, recycling, composting, extended producer responsibility (EPR), technological innovation and policy. It builds on the authors' original assessment of 74 scientific papers retrieved from Scopus and examined through content-based analysis, while relevant recent literature has been added in the revised version to update and strengthen the discussion. Overall, the evidence does not point to one packaging material or circular strategy that is best in every situation. Environmental performance depends on factors such as the function the package must perform, the amount and type of material used, production processes, transport, the number of reuse cycles, washing, collection efficiency, recycling yield and the final treatment route. A package that uses less material, for example, may not deliver an overall benefit if it also leads to more food loss.

Food safety adds another important layer to the discussion. Circular systems can raise questions about chemical migration, contamination, material degradation, the safety of recycled content and the control of substances of concern. Circularity, in other words, should not be assumed to mean either safety or sustainability. Consumer behaviour matters just as much: purchasing, reuse, return, cleaning, sorting and disposal practices all influence whether a circular system works in everyday use. Recent research also suggests that what consumers perceive as sustainable does not always match the actual environmental performance of a package.

Taken together, the review treats food packaging circularity as a socio-technical system that includes packaging design and food preservation, materials and manufacturing, logistics, consumers, collection and recycling infrastructure, business models and regulation. Future research would benefit from moving beyond simple material substitution and stand-alone studies of consumer attitudes towards more integrated assessments that combine LCA, food-waste effects, chemical-safety assessment, behavioural evidence and performance in real operating conditions.

Keywords: Circular economy; sustainable food packaging; packaging circularity; food safety; chemical migration; food-contact materials; life-cycle assessment; food waste; consumer behaviour; reuse; recycling; extended producer responsibility.

1. Introduction

Food packaging does much more than contain a product. It helps protect food from contamination, physical damage, moisture, oxygen, light and other environmental influences; supports storage and transport; enables portioning and convenience; communicates information; and can have a major effect on shelf life and food quality. It is therefore better understood as part of the food system than as a separate material surrounding the product. Any effort to make packaging more sustainable needs to consider how it interacts with food preservation, logistics, consumer use and what happens after use.

The conventional packaging system has largely followed a linear pattern: raw materials are extracted, converted into packaging, used for a relatively short period and then discarded. This is particularly challenging for food packaging because much of it is designed for single use. Large consumption volumes, mixed materials, food residues, multilayer structures and gaps in collection and recycling infrastructure can all make recovery difficult. The resulting impacts include pressure on resources, greenhouse-gas emissions, waste, litter and persistent pollution.

The circular economy provides an alternative way of organising this system. Although there is no single definition of CE, recent scholarship generally links it with reducing resource extraction, keeping products and materials in use, minimising waste and supporting the regeneration of natural systems (Kirchherr et al., 2023). In food packaging, this can mean using less packaging where possible, designing packages for reuse or recycling, using safe recycled materials, considering renewable or biodegradable feedstocks where they are appropriate, improving collection and developing business models that preserve packaging value.

Even so, circular food packaging should not be reduced to replacing conventional plastic with another material. A package can be recyclable in theory but rarely recycled in practice. A reusable container can also have a higher environmental burden than a single-use option if it is not reused often enough, involves inefficient transport or requires large amounts of energy and water for washing. Likewise, a lightweight package may reduce material use but become less sustainable if weaker protection leads to more food loss. These trade-offs are why recent research calls for packaging sustainability to be considered across the whole food-packaging value chain (Martínez-Sánchez et al., 2023).

The link between packaging and food waste deserves particular attention. Packaging has an environmental footprint of its own, but it can also prevent food waste by protecting products and extending shelf life. Because producing food also requires land, water, energy and other resources, avoiding food loss can sometimes outweigh the additional burden created by the packaging. The opposite can also occur: unnecessary or poorly designed packaging may add material without providing a meaningful preservation benefit. Looking only at the package, therefore, can give an incomplete picture of its overall environmental performance.

There is also a clear human-health dimension. Food-contact materials can contain substances that migrate into food, and the extent of migration depends on the material itself as well as food composition, temperature, contact time, storage conditions and structure. Concerns have been raised about substances of concern, endocrine-disrupting chemicals, intentionally added substances and non-intentionally added substances. The use of recycled materials can add further uncertainty where the previous contamination history or chemical composition is not fully known. For this reason, circularity needs to be accompanied by robust safety assessment rather than an assumption that recycled or bio-based materials are automatically safer.

Consumers are another important part of the circular system. Their choices affect whether alternative packaging is accepted, whether reusable containers are returned, whether packaging is cleaned and sorted correctly, and whether it reaches the intended collection stream. Even a technically well-designed circular system can perform poorly when participation is low or instructions are difficult to understand. Du Rietz and Kremel (2024) also found that consumer research in circular food packaging has focused strongly on recycling, with comparatively less evidence on reuse and on consumers in developing-country contexts.

Research also shows that consumers' perceptions of sustainable packaging do not always reflect its actual life-cycle performance. Appearance, labels, the use of natural-looking materials and recyclability claims can all shape perceptions of sustainability, even when the wider environmental picture is more complicated. At the same time, a packaging innovation with genuine environmental advantages may struggle to gain acceptance if it reduces convenience, changes appearance, affects functionality or raises concerns about safety.

These findings point to a broader issue: making food packaging circular is not only a materials or engineering problem. Appropriate infrastructure, economic incentives, policy, reliable information and workable business models are also needed, alongside consumer participation.

In this review, circular food packaging is examined through four connected areas: environmental sustainability, food safety, consumer behaviour and system-level circularity. Particular attention is given to LCA, food-waste prevention, reuse and recycling, chemical migration, consumer participation, EPR and emerging packaging technologies.

The central argument is straightforward: circular food packaging needs to be evaluated as a system, not simply as a property of a material. A packaging option is more meaningfully judged when its environmental, functional, safety, behavioural and economic implications are considered together.

2. Review Methodology

The original manuscript reported a literature review based on 74 scientific papers collected from the Scopus database. Specific keywords were used to identify the literature, which was then refined through detailed content analysis.

The present manuscript keeps that original review basis but reorganises and critically synthesises the evidence around the main dimensions of circular food packaging. It is therefore presented as a critical narrative review rather than as a new systematic review reconstructed according to a PRISMA protocol. Where the original research process did not document screening totals, exclusion counts or search dates, these details have not been added retrospectively.

The literature was organised conceptually around the following themes:

1. circular economy principles and food packaging
2. environmental sustainability and resource efficiency
3. packaging-related food loss and waste
4. food safety and chemical migration
5. recycled and alternative food-contact materials
6. consumer knowledge, attitudes and behaviour
7. life-cycle assessment
8. reuse, recycling and composting
9. circular business models
10. extended producer responsibility and policy
11. technological and material innovations and
12. research gaps and future directions.

To strengthen the original manuscript, relevant recent peer-reviewed studies published around and after the period of the original review were also considered. These studies are used to update the discussion and sharpen the interpretation of the evidence; they are not presented as though they formed part of the original 74-paper search.

This approach is useful because research on circular food packaging is developing quickly. Recent reviews have, for example, examined consumer behaviour, packaging-related food-waste prevention and innovations that connect packaging circularity with food-loss reduction (Du Rietz & Kremel, 2024; de Oliveira et al., 2025). The revised paper draws on these newer syntheses while remaining transparent about the original review design.

3. Circular Economy and Food Packaging

3.1 From a linear to a circular packaging system

The traditional linear model can be represented as:

resource extraction → material production → packaging manufacture → use → disposal

The circular model seeks to replace this pathway with strategies that retain materials and products in productive use for longer:

resource reduction → design → production → use/reuse → collection → recycling/recovery → reintegration

Recycling is only one part of a circular system. The waste hierarchy generally places preventing unnecessary material use and keeping products in use for longer ahead of recycling. For food packaging, this means that reduction, reuse and thoughtful design may, in some situations, deliver greater benefits than recycling alone.

Kirchherr et al. (2023), in their analysis of 221 definitions of the circular economy, show how the concept has grown to include resource reduction, recirculation, value retention and broader system change. For food packaging, these ideas have to be translated into practical decisions about materials, design, production, use and recovery.

A genuinely circular package needs to be considered across its whole life cycle. That includes where its raw materials come from, how it is manufactured, how it performs in food contact, how it is transported and used, and what happens during collection, sorting, reuse, recycling or disposal. In this sense, designing for circularity is more useful than simply describing an existing package as "recyclable."

3.2 Circularity is not synonymous with sustainability

A recurring problem in the literature is the tendency to treat terms such as sustainable, circular, recyclable, biodegradable, compostable and bio-based as though they mean the same thing. They do not. Each describes a different property or pathway.

For example, a bio-based package is not necessarily biodegradable, and a biodegradable material is not necessarily compostable under industrial conditions. Compostable packaging may need a dedicated collection and treatment system, while a recyclable package may not actually be collected or recycled in a particular location. Recycled content can reduce demand for virgin material, but food-contact applications may also require additional safety and quality controls.

Martínez-Sánchez et al. (2023) similarly emphasised that sustainable food packaging needs to be considered in relation to packaging function, food safety and the wider food value chain, rather than through a single material characteristic.

For that reason, packaging sustainability is best judged in relation to its function and the context in which the packaging system operates.

3.3 Packaging as part of the food system

Packaging cannot be separated from the food it is intended to protect. By limiting exposure to oxygen, moisture, microorganisms and physical damage, it can extend shelf life and reduce food loss. Portion sizes, resealable formats and controlled dispensing can also affect how food is managed at household level.

This is why removing packaging without considering the preservation function it provides can lead to unintended consequences. The more useful question is not simply:

"How much packaging is used?"

but rather:

"How much packaging is required to deliver the required food-protection function with the lowest overall environmental burden?"

This distinction is central to any assessment of circular food packaging.

4. Environmental Sustainability of Circular Food Packaging

4.1 Resource use and greenhouse-gas emissions

Producing packaging requires raw materials, energy and processing. Fossil-based plastics receive considerable attention because they rely on non-renewable resources and can persist after disposal. Alternative materials are not impact-free, however; their production may involve land and water use, agricultural inputs, processing energy and additional transport.

For this reason, replacing plastic with another material does not automatically reduce environmental impacts. The performance of glass, metal, paper, biopolymers and reusable systems varies with factors such as production methods, material quantity, transport distance, reuse frequency and end-of-life treatment.

Hussain et al. (2024) describe a growing range of sustainable packaging materials and technologies, including bio-based polymers, active packaging and intelligent packaging. These developments offer useful opportunities, but their environmental value still depends on whether they meet food-protection requirements, remain economically practical, are safe for food contact and can be managed appropriately at end of life.

4.2 Packaging reduction and lightweighting

Using less material per functional unit of food is one of the most direct ways to reduce resource use. Lightweighting can also reduce the material required for production and the weight transported through the supply chain.

There is, however, a limit to how far lightweighting can go. If thinner packaging loses mechanical strength, barrier performance or shelf life, the resulting food loss may cancel out the material savings.

The aim should therefore be to use the minimum amount of material that still provides the required packaging function, rather than simply pursuing the lowest possible material weight.

4.3 Reuse

Reuse keeps packaging in circulation instead of requiring a new package for every purchase. Its environmental advantage, however, depends on how often the package is reused and, on the resources, needed to collect, wash and redistribute it.

A reusable system involves several additional processes:

- return or collection
- transportation
- inspection;
- cleaning and sanitisation
- drying
- redistribution
- replacement of damaged containers.

Yadav et al. (2024) show why these operational details matter. Their LCA indicates that reusable plastic food packaging can perform better than single-use alternatives under suitable conditions, but the result is sensitive to factors such as reuse frequency, customer transport and washing efficiency.

The common claim that "reusable is always more sustainable" is therefore too broad. The environmental case for reuse needs to be demonstrated using realistic assumptions about how the system will operate.

4.4 Recycling

Recycling can keep material in use and reduce the need for virgin resources. Mechanical recycling is already established for a number of packaging materials, while chemical and other advanced recycling approaches are being developed for more complex waste streams.

Food packaging is particularly challenging to recycle because it may carry food residues and contain different polymers, additives, adhesives, coatings or barrier layers. Multilayer structures can be valuable for protecting food, but that same complexity can make material recovery more difficult.

The effectiveness of recycling therefore depends on:

- collection rates
- sorting efficiency
- contamination levels
- material compatibilit
- recycling yield
- quality of recycled output
- market demand for secondary materials and
- regulatory requirements.

A recycling symbol alone is not evidence that a package will be recycled. The distinction between being recyclable in principle and being recovered and recycled in the actual waste system is important.

4.5 Compostable and biodegradable packaging

Compostable packaging is often discussed as an alternative for food applications where food contamination makes conventional recycling difficult. It can be useful in some settings, but its benefits depend on what happens after the package is discarded.

Compostability is tied to specific conditions. Materials designed for industrial composting may not break down in unmanaged environments or ordinary landfill conditions. They can also create problems if they enter conventional recycling streams and contaminate recyclable material.

For compostable packaging to deliver the intended end-of-life benefit, suitable collection and treatment infrastructure needs to exist. Without it, the claimed advantage may remain largely theoretical.

4.6 Food waste as a critical environmental trade-off

A major shift in packaging research has been the recognition that packaging-related food waste needs to be considered alongside the packaging itself.

Hemachandra et al. (2024) found that only a relatively small number of food-packaging LCAs explicitly accounted for packaging-related food waste. This matters because the environmental footprint of the food being protected can be much larger than that of the package.

For a highly perishable product, a modest increase in packaging may be justified if it substantially extends shelf life and prevents food from being wasted. If the same packaging change offers little preservation benefit, however, the additional material may simply add to the environmental burden.

Therefore:

Packaging sustainability = packaging impacts + food-system impacts

rather than:

Packaging sustainability = packaging impacts alone.

This broader view should be carried into future assessments of circular food packaging.

5. Food Safety, Chemical Migration and Human Health

5.1 Food-contact materials and safety

Food packaging may come into direct or indirect contact with food and must meet applicable food-contact safety requirements. Packaging can contain polymers, additives, pigments, stabilisers, adhesives, coatings and other substances, some of which can migrate into food under particular conditions.

Migration depends on factors including:

- temperature
- contact duration
- food composition
- fat content
- acidity
- packaging material
- surface area-to-volume ratio
- storage conditions and
- chemical properties of the migrating substance.

The presence of a chemical in packaging does not, by itself, establish a health risk. A proper risk assessment needs to consider the substance's hazard, the level of exposure and the available toxicological evidence.

5.2 Chemical migration

Migration deserves particular attention in circular packaging because changes in material composition, processing or the use of recycled content can alter the chemical profile of the material.

Muncke et al. (2020) highlighted the need to consider the wide range of chemicals that can occur in food-contact materials, including both intentionally added substances and non-intentionally added substances.

Stevens et al. (2024) also reported endocrine- and metabolism-disrupting chemicals in plastic food packaging, underlining the need for better chemical transparency and careful safety assessment.

These findings should not be read as evidence that all plastic packaging causes adverse health effects. They do, however, show why packaging safety should be established through scientific assessment rather than inferred from labels such as "plastic-free," "natural," "bio-based" or "recycled."

5.3 Recycled materials and food-contact applications

Using recycled material is an important part of the circular economy, but food-contact applications place particularly strong demands on the control of contamination and material quality.

Post-consumer packaging may have been exposed to:

- non-food substances;
- cleaning agents;
- pesticides;

- household chemicals;
- unknown contaminants; and
- other packaging materials.

Recycling processes may remove, dilute or transform some contaminants, but this cannot simply be assumed for every substance or process. Reliable collection, sorting, decontamination and regulatory controls are needed to make recycled food-contact materials suitable for their intended use.

The practical challenge is to keep materials circulating without compromising food-contact safety.

These goals do not need to be treated as opposing objectives; a well-designed circular system should be capable of addressing both.

5.4 Circularity does not automatically improve human health

The earlier version of the manuscript at times linked circular packaging too directly with improved human-health outcomes. That wording goes beyond what the available evidence can support.

Circular strategies may reduce certain environmental pressures or particular exposure pathways, but they do not automatically lead to measurable improvements in human health. Health outcomes are shaped by many factors, including chemical exposure, food quality, nutrition, environmental pollution and socioeconomic conditions.

A more defensible conclusion is that circular packaging systems can contribute to reducing particular environmental or chemical risks when suitable materials, controls and regulatory requirements are in place.

6. Consumer Behaviour and Circular Packaging

6.1 The consumer as an active participant

Consumers are not simply the final users of packaging; their actions can determine whether a circular system works as intended. Reuse, return, sorting, cleaning and disposal all depend, to some extent, on what people actually do.

Du Rietz and Kremel (2024) found that research on consumer behaviour in circular food packaging has focused largely on recycling and has been concentrated in Europe and the United States. Their review also points to limited evidence from developing-country settings.

This matters because consumer participation is closely tied to context. Household practices, income, cultural expectations, convenience, local waste infrastructure and access to collection facilities can all shape behaviour.

6.2 Attitude–behaviour gaps

Environmental concern on its own does not guarantee sustainable packaging behaviour.

A consumer may support recycling but still sort packaging incorrectly, or favour reusable packaging in principle while choosing single-use options because they are easier. Sustainability may also be important while price, food safety, quality, shelf life and convenience remain the deciding factors.

This phenomenon illustrates the importance of distinguishing:

- environmental attitudes;
- behavioural intentions;
- actual behaviour; and
- system outcomes.

High stated willingness to recycle or reuse should therefore be interpreted carefully. Such responses indicate attitudes or intentions, but they do not necessarily predict high return rates or effective recycling in everyday settings.

6.3 Consumer perceptions of sustainable packaging

Consumer perceptions of sustainable packaging are not shaped by environmental considerations alone. Factors such as perceived food quality, safety, affordability, trust and the availability of clear product information can influence how consumers evaluate sustainability-related attributes and make purchasing decisions. This suggests that sustainability needs to be considered alongside the broader set of product attributes that consumers use when forming their perceptions and making choices (Balachandran & Chaturvedi, 2025).

The way packaging looks can strongly influence how sustainable it seems. Paper, glass, natural fibres and earthy colours, for instance, may be associated with environmental friendliness even when the full life-cycle picture is more complicated.

In their systematic review of 79 peer-reviewed articles, D'Aniello et al. (2025) found that consumer responses are shaped by packaging design, awareness, the interaction of several product attributes and the consistency of sustainability cues.

This makes clear communication important. Broad labels such as "eco-friendly" can mean different things to different consumers and may create confusion when the specific environmental benefit is not explained.

6.4 Convenience and participation

Convenience remains one of the strongest practical influences on consumer behaviour.

Reusable systems can require consumers to:

1. return packaging
2. remember collection schedules
3. clean or store containers
4. transport containers
5. pay deposits
6. accept standardised formats

These requirements create behavioural costs.

A circular system may look environmentally attractive on paper but perform less well if participation is difficult. Designing the system so that the required consumer effort is as small and straightforward as possible is therefore important.

6.5 Consumer information

Clear instructions can make sorting and participation easier. Labels, digital information, QR codes and other smart-packaging tools can communicate:

- whether packaging is recyclable
- where it should be returned
- whether it requires cleaning
- whether it is reusable
- what material it contains and
- how it should be disposed of.

Information helps, but it cannot make up for missing infrastructure. A consumer cannot recycle a package if the local system does not collect or process that material.

7. Life-Cycle Assessment and System-Level Evaluation

LCA is one of the main tools used to compare packaging alternatives, but its conclusions are only as reliable as the assumptions and system boundaries behind the assessment.

7.1 Functional unit

The functional unit should describe the service that the packaging provides, rather than comparing materials simply by mass.

For example, comparing one kilogram of two packaging materials may be misleading if one provides substantially better protection or shelf life than the other.

A more appropriate functional unit may involve:

delivery of a defined quantity of safe, acceptable food to the consumer while maintaining specified quality and shelf life.

This makes it possible to compare packaging according to what it actually delivers to the food system.

7.2 System boundaries

Packaging LCAs may include

- raw-material extraction
- material processing
- packaging production
- filling
- transportation
- retail
- consumer use
- washing
- collection
- sorting
- recycling
- disposal.

The choice of system boundary can change the result of an LCA. For reusable packaging, leaving out washing or reverse logistics can make impacts look artificially low, while unrealistic assumptions about transport or very low reuse rates can push the result in the opposite direction.

For this reason, LCA scenarios should reflect how the packaging system is expected to operate in practice.

7.3 Reuse cycles

The number of times a package is reused is one of the most influential variables in a reuse assessment.

A container used hundreds of times is very different from one used only a few times. As the number of cycles increases, the manufacturing burden is spread across more uses, although each additional cycle still carries the impacts of transport, cleaning and handling.

Reuse also has a practical limit. Containers eventually need replacement, and every cycle consumes resources for cleaning and transport.

Yadav et al. (2024) similarly highlight the importance of reuse frequency and operating conditions when evaluating reusable food packaging.

7.4 Consumer transport

Consumer travel can also affect the environmental performance of a reusable system.

If people make a separate trip to return containers, the additional travel can add emissions. If returns happen during normal shopping trips or are built into existing collection routes, the additional burden may be much smaller.

This is one reason consumer behaviour is increasingly relevant to packaging LCA.

Corona et al. (2024) found that consumer decisions can affect packaging environmental profiles through packaging choice, transport, use and end-of-life behaviour.

7.5 Washing and sanitisation

Washing is a central part of most reusable packaging systems.

Environmental performance depends on:

- water consumption
- detergent use
- electricity or heat
- washing efficiency
- container design
- drying requirements
- contamination level and
- number of containers processed per cycle.

Efficient industrial washing can provide different results from household washing.

Industrial washing and household washing can have very different environmental profiles. LCA assumptions should therefore reflect realistic operating conditions wherever reliable data are available.

7.6 Packaging and food waste

LCAs that leave food waste out of the analysis can miss an important part of the picture. Packaging that prevents food loss may create environmental benefits that are much larger than the impacts of the package itself.

Espinoza-Orias and Lundquist (2025) emphasised the need to account for food losses and food waste when evaluating reusable packaging systems.

Future LCAs should therefore integrate:

Future LCAs would therefore benefit from bringing together packaging production, logistics, use, end-of-life processes and the consequences of food waste in the same assessment.

8. Reuse, Recycling, Composting and Circular Business Models

8.1 Reuse systems

Reuse can occur through:

- refill models
- deposit-return systems

- returnable transport packaging
- reusable takeaway containers
- reusable retail containers and
- closed-loop commercial systems.

Closed-loop systems can make collection easier because packaging stays within a defined network. Open-loop systems are more difficult to control because containers can leave the network and enter general waste streams.

8.2 Deposit-return systems

A deposit-return system gives consumers a financial reason to return packaging.

The basic model is:

purchase → deposit payment → consumption → return → deposit refund → collection → processing

By attaching a monetary value to the package, such systems can encourage higher return rates.

Their success still depends on how the scheme is designed, how convenient it is, the collection infrastructure available, the size of the deposit and whether consumers participate consistently.

8.3 Recycling systems

Recycling depends on coordination across the whole value chain. Producers need to consider recyclability at the design stage, while municipalities and waste operators need systems for collection and sorting.

Circularity therefore depends on coordination between:

design → collection → sorting → processing → secondary market.

If any part of this chain breaks down, the amount of material actually recovered can fall.

8.4 Circular business models

Circular business models can change how packaging is owned, supplied, returned and valued by producers, retailers and consumers.

Instead of treating packaging as something disposable, businesses can provide packaging as part of a service. Examples include:

- container leasing
- deposit-return systems
- refill stations
- subscription models
- packaging take-back schemes
- pooled reusable containers.

These models can give companies a stronger reason to design durable packaging because the package retains value beyond its first use.

At the same time, they require additional coordination, logistics and organisational effort.

9. Extended Producer Responsibility and Policy

Extended Producer Responsibility (EPR) gives producers greater responsibility for packaging after it has been placed on the market and used. Depending on the system, this can include contributing to collection, recovery and recycling infrastructure.

OECD analysis notes that EPR is being extended to additional product groups and that effective producer responsibility needs to take the wider product life cycle into account.

9.1 Potential benefits

EPR can:

- create financial incentives for waste management
- encourage design for recyclability
- improve collection
- support recycling infrastructure
- shift some waste-management costs upstream
- generate information about packaging flows.

9.2 Limitations

EPR can support circularity, but it does not guarantee it.

Its effectiveness depends on:

- enforcement
- fee structures
- producer participation
- monitoring
- recycling capacity
- informal-sector integration where relevant
- market demand for recycled materials
- quality of reporting.

If an EPR scheme is poorly designed, it may simply shift waste-management costs upstream without creating much change in packaging design or recovery performance.

9.3 Eco-modulation

Eco-modulated EPR fees are designed to make the financial signal stronger or weaker depending on packaging characteristics.

For example, fees can potentially be lower for packaging that is:

- readily recyclable
- made with recycled content
- lightweight
- reusable
- free of problematic substances.

This creates a direct link between policy incentives and packaging-design decisions.

This can connect policy incentives with packaging design.

9.4 Policy must reflect local infrastructure

A packaging format that works well in one country may perform quite differently in another because collection, sorting and recycling systems are not the same.

Policy should therefore be cautious about promoting a single material solution as though it will work everywhere.

This is especially relevant in countries where waste-management systems are mixed, informal collection plays an important role, or recycling capacity varies considerably.

10. Technological and Material Innovations

10.1 Bio-based materials

Bio-based polymers and fibre-based materials can reduce reliance on fossil resources in some applications.

Their overall sustainability, however, depends on how the feedstock is produced, as well as land and water use, processing energy, durability and what happens to the material after use.

Being bio-based is therefore not, by itself, evidence of a low environmental impact.

10.2 Active packaging

Active packaging is designed to interact with food or the surrounding environment in order to help maintain quality. Examples include oxygen scavengers, moisture absorbers and antimicrobial systems.

These approaches may help extend shelf life and reduce food waste.

At the same time, any active substance intended for use with food needs appropriate assessment for safety and migration.

10.3 Intelligent packaging

Intelligent packaging provides information about the condition of food or its exposure to the surrounding environment.

Examples include:

- freshness indicators
- time-temperature indicators
- sensors
- digital identification
- QR-based consumer information.

Such technologies could help reduce food waste by giving consumers and retailers better information about product condition.

10.4 Nanotechnology

Nanomaterials may improve barrier properties, mechanical strength and other packaging functions.

Their use also raises additional questions about safety and regulation, so migration, exposure and toxicological properties need to be assessed carefully for food-contact applications.

10.5 Digitalisation and traceability

Digital technologies can support circular systems by improving the tracking of packaging materials, return flows and recycling information.

Digital product passports and related tools could improve transparency about material composition and possible recovery routes.

They should, however, be seen as supporting tools rather than replacements for the physical infrastructure needed to collect, sort, reuse or recycle packaging.

11. Critical Synthesis: Trade-Offs and System-Level Barriers

Across the literature, one point comes through clearly: moving towards circular food packaging involves a series of trade-offs rather than a single straightforward solution.

11.1 Environmental versus food-safety objectives

Using recycled material can reduce demand for virgin resources, but it may also require stronger controls to ensure food-contact safety. Similarly, reducing packaging weight can lower material use while potentially weakening protection.

11.2 Reuse versus logistics

Reusable packaging can reduce material demand over several cycles, but those benefits have to be weighed against reverse logistics, washing and the resources needed to operate the return system.

11.3 Recycling versus functionality

Multilayer structures often provide strong barrier performance, yet their complexity can make recycling more difficult.

11.4 Compostability versus infrastructure

Compostable packaging may be suitable for some applications, but its potential benefit is limited when the required industrial composting infrastructure is not available.

11.5 Consumer convenience versus circularity

Circular systems can place additional demands on consumers. When returning, cleaning or sorting packaging is inconvenient, participation can fall and the expected environmental benefit may not be achieved.

11.6 Sustainability claims versus consumer understanding

Consumers may also treat terms such as “biodegradable,” “natural,” “recyclable” and “eco-friendly” as though they mean the same thing, even though they refer to different properties or end-of-life pathways.

Clearer communication and more consistent terminology can help reduce this gap between sustainability claims and consumer understanding.

12. Research Gaps and Future Research

Several areas of the literature still need stronger evidence.

12.1 More real-world evidence

A considerable number of studies examine hypothetical packaging systems rather than systems operating at scale. More operational data would help establish actual reuse and return rates, washing performance and recycling yields.

12.2 Integration of consumer behaviour into LCA

Consumer behaviour should be part of environmental assessment rather than being treated as a separate social issue.

Future models should account for:

- return probability

- sorting behaviour
- consumer transport
- cleaning behaviour
- reuse frequency
- participation rates.

12.3 Greater attention to developing economies

Much of the existing consumer research comes from a relatively limited set of geographical contexts. More evidence from Asia, Africa, Latin America and other regions is needed because packaging practices, infrastructure and consumer behaviour can differ substantially.

12.4 Food-safety assessment of circular materials

Further research is needed on the safety of recycled materials as well as emerging biopolymers, additives, coatings and active packaging.

12.5 Long-term chemical exposure

Longer-term work should pay more attention to cumulative exposure and mixtures of food-contact chemicals, rather than considering substances only one at a time.

12.6 Food waste integration

Packaging studies should also bring food-waste consequences more consistently into environmental assessment.

12.7 Standardised circularity metrics

There is a need for clearer metrics that distinguish:

- theoretical recyclability
- collection
- actual recycling
- recycled-content utilisation
- reuse cycles
- material retention.

12.8 Social and economic dimensions

Research on circular packaging should also consider affordability, employment, accessibility, equity and how costs and benefits are distributed among different stakeholders.

13. Implications for Industry

Food manufacturers and packaging companies should avoid making packaging choices on the basis of a single sustainability attribute.

Instead, packaging decisions should consider:

1. required food-protection performance
2. material quantity
3. food-contact safety
4. recycled-content potential
5. actual recyclability

6. reuse potential
7. transportation requirements
8. food-waste implications
9. consumer convenience
10. end-of-life infrastructure.

A design-for-system approach is more appropriate, with the package considered together with the food, logistics, consumers and end-of-life system around it.

Industry should also be careful with broad environmental claims. Statements such as "100% sustainable," "zero impact" or "eco-friendly" can hide important life-cycle trade-offs.

Communication is more useful when it explains the specific environmental characteristic that has been improved and, where relevant, the conditions under which the benefit applies.

14. Implications for Policymakers

Policymakers should focus on creating the conditions in which circular systems can work, rather than relying only on bans of individual materials.

Priority areas include:

- harmonised packaging standards;
- EPR systems;
- eco-modulated fees;
- deposit-return schemes where appropriate;
- recycling infrastructure;
- reuse infrastructure;
- food-contact safety regulation;
- standards for environmental claims;
- consumer education;
- data collection;
- support for innovation.

Policy also needs to reflect local circumstances. The most suitable balance among reduction, reuse, recycling and composting depends on infrastructure, waste-management capacity and consumption patterns.

15. Integrated Conceptual Framework

The evidence brought together in this review suggests that circular food packaging is best understood through a set of connected factors rather than a single measure such as recyclability, renewable content or waste reduction. Packaging design, food functionality and safety, environmental performance, consumer behaviour, infrastructure and business models, and policy and governance all interact across the life cycle. Together, they determine whether a proposed circular system can deliver environmental gains while still protecting food, meeting safety requirements, being acceptable to consumers and remaining workable in practice.

15.1 Packaging Design

Packaging design is one of the earliest points at which circularity can be influenced. Choices about material type and quantity, structural complexity, durability, separability and compatibility with existing reuse or recycling systems shape what happens later in the life cycle. Useful approaches include source reduction, lightweighting, mono-material structures, design for recycling, design for reuse and avoiding unnecessary components.

Design choices should not, however, be judged in isolation. A lightweight or recyclable package may offer little overall benefit if it weakens food protection, increases food loss or cannot be collected and processed through the system available in the intended market. The design question is therefore not simply how to make a package recyclable, but how to make it perform its required function within a workable circular system.

15.2 Food Functionality and Safety

The first responsibility of food packaging is to protect food from physical, chemical and microbiological hazards while maintaining quality and shelf life. Circular strategies should not compromise that role.

This matters because packaging and food waste are closely linked. Using fewer resources for the package is not necessarily an environmental improvement if shelf life falls and more food is wasted. On the other hand, packaging that genuinely extends shelf life can avoid the environmental impacts associated with producing food that would otherwise be lost.

Food safety also sets an important boundary for circularity. Reuse and recycling can bring additional concerns related to cleaning, contamination, chemical migration, material degradation and the possible transfer or accumulation of substances. Circular systems therefore need to demonstrate appropriate food-contact safety and risk controls rather than assuming that circular materials are safe by default.

15.3 Environmental Performance

Environmental performance covers the impacts associated with raw materials, material production, packaging manufacture, transport, use, collection, reuse, recycling and final disposal or recovery. Depending on the study, relevant measures can include greenhouse-gas emissions, energy and water use, resource depletion, pollution and waste.

A material label cannot tell the whole environmental story. Recyclable, biodegradable, compostable, bio-based and reusable describe particular characteristics or pathways; none of them, on its own, guarantees overall sustainability. What matters is how the option performs across its life cycle and within the system where it is actually used.

LCA is valuable for making these comparisons, but its findings depend on choices about the functional unit, system boundaries, transport, washing, reuse cycles, collection rates, recycling efficiency and food-waste effects. Environmental results are therefore more useful when interpreted alongside food functionality, consumer behaviour and the infrastructure available in the target context.

15.4 Consumer Behaviour

Consumer behaviour connects packaging design with what happens in practice. Consumers decide whether to accept and purchase alternative formats and, where required, whether to reuse, return, clean, sort and dispose of packaging correctly. A package can be technically recyclable or reusable and still achieve poor circular outcomes if the required behaviours do not occur.

People’s responses are shaped by convenience, perceived functionality, price, hygiene concerns, environmental awareness, trust, labelling and perceived benefits. Environmental attitudes do not always translate into consistent behaviour. Participation is more likely when the required actions are straightforward and supported by infrastructure that makes them possible.

15.5 Infrastructure and Business Models

Circular packaging needs more than a suitable material; it needs physical and organisational systems that keep packaging in use. These can include collection and sorting, recycling facilities, washing and sanitisation, reverse logistics, refill networks, deposit-return schemes, take-back programmes and reuse services.

Business models matter because circular packaging can change who owns the package, how it moves through the supply chain and how it is recovered. Reuse and refill models, for instance, depend on coordinated returns rather than a one-way transaction. Their feasibility is influenced by return rates, transport distance, cleaning requirements, utilisation and the scale of the network.

15.6 Policy and Governance

Policy and governance create the wider conditions in which circular packaging systems operate. EPR, packaging standards, material regulations, economic incentives, recycled-content requirements, waste-management rules, monitoring and consumer information can all influence decisions made by producers, retailers, consumers and waste operators.

Policy measures are not automatically effective, however. Their results depend on implementation capacity, enforcement, infrastructure, market conditions, data quality and the way financial incentives are designed. Policy is therefore most useful when it is aligned with the technical and behavioural realities of the packaging system and adapted to local conditions.

15.7 Interactions Among the Dimensions

The six dimensions are closely connected rather than independent. Their interactions create feedback across the packaging life cycle.

For example:

Packaging design → consumer convenience → consumer participation → collection and return efficiency → recycling/reuse performance → environmental outcome.

Similarly:

Packaging design → food protection and shelf life → food loss and waste → total environmental impact.

A further interaction occurs between infrastructure and consumer behaviour:

Infrastructure availability → convenience of return/sorting → consumer participation → material recovery → economic viability of the circular system.

Policy can influence all of these relationships by establishing requirements and incentives:

Policy and governance → packaging design and business incentives → infrastructure investment → consumer participation → circular-system performance.

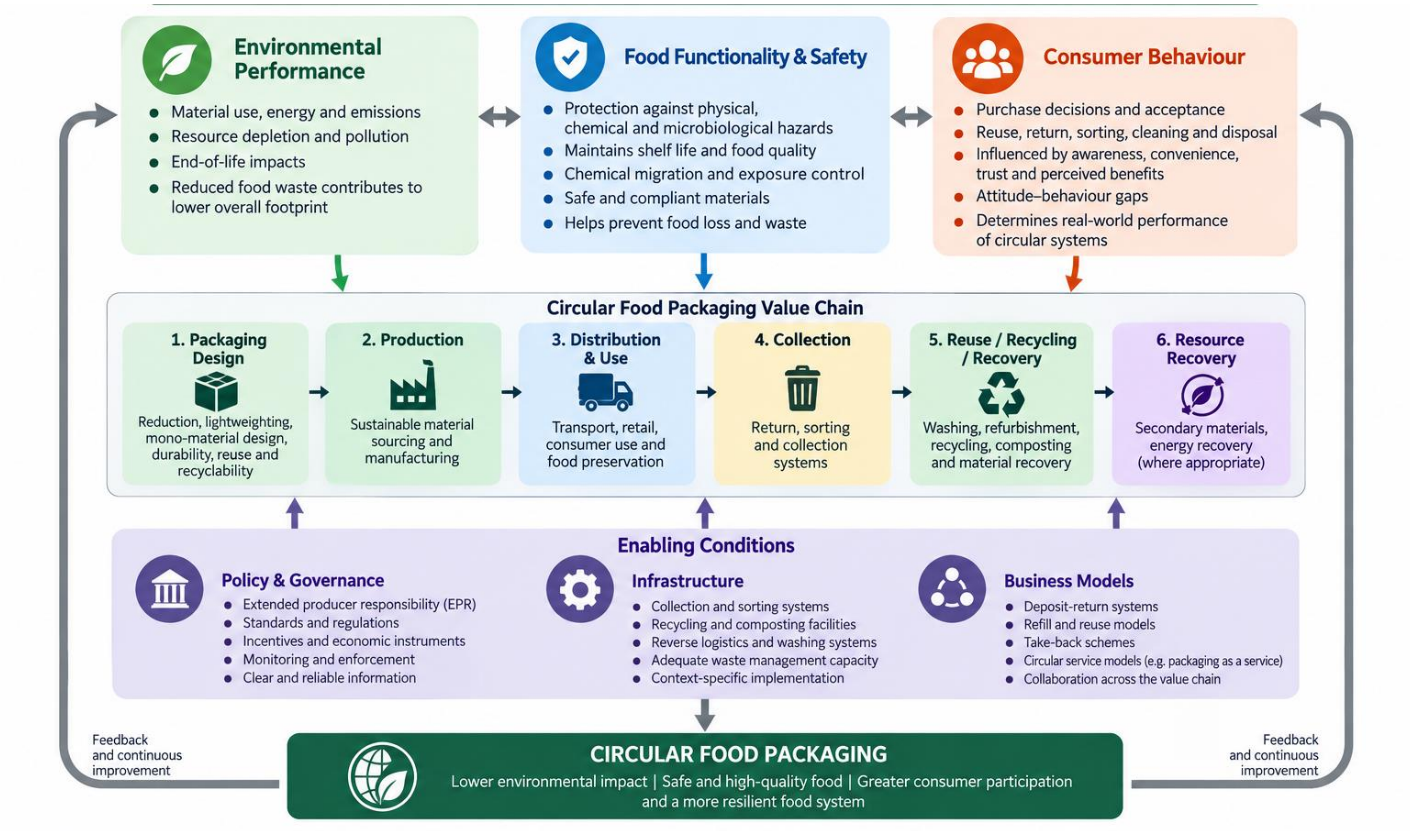
Taken together, these relationships show why a packaging material should not be judged in isolation. The same material can perform differently depending on collection arrangements, transport distances, reuse frequency, consumer participation, recycling efficiency and the regulatory setting.

15.8 Circularity as an Emergent System Property

These relationships support the view that circularity is an outcome of the system rather than a fixed property of a particular packaging material. A package becomes meaningfully circular when its design, functionality, environmental performance, consumer use, infrastructure, business model and governance arrangements work together to keep resources in productive use while maintaining food quality and safety.

The framework therefore moves beyond a material-centred view of sustainable food packaging. It recognises that an apparently circular strategy can lose its environmental advantage, or even create new burdens, when it involves excessive transport, energy-intensive washing, contamination, food waste, low return rates or ineffective recycling. The framework provides a basis for assessing circular food packaging by looking at environmental outcomes, food protection and safety, consumer participation and the practical conditions that allow circularity to function.

Figure 1. Integrated Conceptual Framework for Circular Food Packaging: Interactions Among Environmental Sustainability, Food Safety, Consumer Behaviour, and Enabling System Conditions



16. Conclusion

Food packaging has a difficult but important role within the circular economy. It contributes to environmental burdens, yet it is also essential for protecting food, extending shelf life and preventing food loss. Moving towards circular packaging therefore involves more than replacing a conventional material with an alternative one.

The evidence reviewed here supports a life-cycle and system-level approach. Reduction, reuse, recycling, composting and renewable materials can all play a role when the conditions are right, but none can be treated as the best solution in every case. Environmental performance depends on material requirements, production, logistics, reuse frequency, washing, collection, recycling efficiency and what happens at end of life.

Food safety remains a non-negotiable requirement. Circularity does not automatically make a package safe, and recycled or alternative materials need appropriate assessment of contamination, chemical migration and food-contact compliance. In the same way, claims of environmental benefit should not rest only on labels such as recyclable, biodegradable, compostable or bio-based.

Consumers also influence whether circular systems deliver what they promise. Their decisions affect reuse, return, recycling and disposal, but stated intentions should not be treated as a direct substitute for observed behaviour. Convenience, infrastructure, trust, information and economic incentives all influence participation.

Food waste is particularly important in this discussion. Packaging should not be assessed only on the burden created by the package itself because effective packaging can prevent food loss and the environmental impacts associated with wasted food. Future LCAs would be stronger if they incorporated food-waste consequences together with realistic consumer behaviour, reuse cycles, washing, reverse logistics and actual recycling performance.

EPR, deposit-return systems, circular business models and new packaging technologies can help move the sector towards greater circularity, but their success depends on how they are implemented and on the context in which they operate. Policies are therefore more likely to be effective when they support functioning systems rather than focus only on individual materials.

Overall, moving food packaging towards circularity will require cooperation among packaging manufacturers, food producers, retailers, consumers, waste-management organisations, regulators and researchers. The most sustainable option is not necessarily the package with the lowest material footprint, the highest recycled content or the strongest environmental claim. A better choice is the one that provides the required protection for the food while keeping overall environmental and safety burdens low and working within the social, economic and infrastructural conditions of the system in which it is used.

The central message of this review is that food packaging circularity is a socio-technical issue. Environmental sustainability, food safety, food preservation, consumer behaviour, infrastructure, business models and policy depend on one another. Future research should move beyond isolated material substitution and develop integrated assessments that can show when, where and under what conditions particular circular strategies deliver meaningful environmental and societal benefits.

References

1. Kirchherr, J., Yang, N.-H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): An analysis of 221 definitions. *Resources, Conservation and Recycling, 194*, 107001. https://doi.org/10.1016/j.resconrec.2023.107001
2. Du Rietz, S., & Kremel, A. (2024). Consumer behavior as a challenge and opportunity for circular food packaging—a systematic literature review. *Circular Economy and Sustainability, 4*, 413–438. https://doi.org/10.1007/s43615-023-00290-1
3. Ada, E., Kazancoglu, Y., Lafcı, Ç., Ekren, B. Y., & Çimitay Çelik, C. (2023). Identifying the drivers of circular food packaging: A comprehensive review for the current state of the food supply chain to be sustainable and circular. *Sustainability, 15*, 11703. https://doi.org/10.3390/su151511703
4. Martínez-Sánchez, L., et al. (2023). Sustainable food packaging: An updated definition following a holistic approach. *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2023.1119052
5. Corona, B., Tunn, V. S. C., & van den Broek, K. L. (2024). Integrating consumer behaviour into the environmental assessment of circular packaging: A scoping review. *The International Journal of Life Cycle Assessment, 29*, 80–98. https://doi.org/10.1007/s11367-023-02218-1
6. Yadav, P., Silvenius, F., Katajajuuri, J.-M., & Leinonen, I. (2024). Life cycle assessment of reusable plastic food packaging. *Journal of Cleaner Production, 448*, 141529. https://doi.org/10.1016/j.jclepro.2024.141529
7. Espinoza-Orias, N., & Lundquist, L. (2025). Life cycle assessment of reusable food and beverage packaging systems: A proposal of good practice. *Journal of Cleaner Production, 499*, 145207. https://doi.org/10.1016/j.jclepro.2025.145207
8. Hemachandra, S., Hadjikakou, M., & Pettigrew, S. (2024). A scoping review of food packaging life cycle assessments that account for packaging-related food waste. *The International Journal of Life Cycle Assessment, 29*, 1899–1915. https://doi.org/10.1007/s11367-024-02349-z
9. D'Aniello, A., Donato, C., & Stagno, E. (2025). Packaging the future: A research agenda to unveil consumer trends in sustainable food and beverage choices. *Business Strategy and the Environment, 34*(7), 8779–8831. https://doi.org/10.1002/bse.70037
10. de Oliveira, M. M., Lago, A., Pinto, N. G. M., et al. (2025). Systematic review of innovations in food packaging with a focus on circularity and the reduction of food loss and waste. *Discover Applied Sciences, 7*, 1133. https://doi.org/10.1007/s42452-025-07788-3

11. Hussain, S., Akhter, R., & Maktedar, S. S. (2024). Advancements in sustainable food packaging: From eco-friendly materials to innovative technologies. *Sustainable Food Technology, 2*, 1297–1364. https://doi.org/10.1039/D4FB00084F

12. Muncke, J., Andersson, A.-M., Backhaus, T., et al. (2020). Impacts of food contact chemicals on human health: A consensus statement. *Environmental Health, 19*, 25. https://doi.org/10.1186/s12940-020-0572-5

13. Gupta, P., et al. (2024). Migration of chemical compounds from packaging materials into packaged foods: Interaction, mechanism, assessment, and regulations. *Foods, 13*, 3125.

14. Stevens, A. S., et al. (2024). Plastic food packaging from five countries contains endocrine- and metabolism-disrupting chemicals. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.3c08250

15. Gündoğdu, S., et al. (2024). Microplastics and chemical risks associated with plastic food packaging. *Science of the Total Environment, 946*, 174000.

16. Deeney, M., Green, R., Yan, X., Dooley, C., Yates, J., Rolker, H. B., & Kadiyala, S. (2023). Human health effects of recycling and reusing food sector consumer plastics: A systematic review and meta-analysis of life cycle assessments. *Journal of Cleaner Production, 397*, 136567. https://doi.org/10.1016/j.jclepro.2023.136567

17. Pearson, A. J., Mukherjee, K., Fattori, V., et al. (2024). Opportunities and challenges for global food safety in advancing circular policies and practices in agrifood systems. *npj Science of Food, 8*, 60.

18. Van der Fels-Klerx, H. J., van Asselt, E. D., Berendsen, B., et al. (2024). Framework for evaluation of food safety in the circular food system. *npj Science of Food, 8*, 36.

19. Dey, A., & Ashok, S. D. (2024). Fuzzy logic based qualitative indicators for promoting extended producer responsibility and sustainable food packaging waste management. *Environmental and Sustainability Indicators, 24*, 100534. https://doi.org/10.1016/j.indic.2024.100534

20. Flygansvær, B., & Dahlstrom, R. (2024). Enhancing circular supply chains via ecological packaging: An empirical investigation of an extended producer responsibility network. *Journal of Cleaner Production*, 142948. https://doi.org/10.1016/j.jclepro.2024.142948

21. Ramasubramanian, B., Tan, J., Chellappan, V., & Ramakrishna, S. (2023). Recent advances in extended producer responsibility initiatives for plastic waste management in Germany and UK. *Circular Economy and Sustainability*. https://doi.org/10.1007/s42824-023-00076-8

22. Ezeudu, O. B. (2024). Harnessing the drivers and barriers to implementation of extended producer responsibility for circular economy in Nigeria. *Circular Economy and Sustainability*. https://doi.org/10.1007/s43615-023-00340-8

23. Poonia, V., Sangwan, K. S., Kulshrestha, R., & Shah, J. D. (2024). Overcoming the extended producer responsibility challenges of packaging material through integrated refurbishing and recycling. *Process Integration and Optimization for Sustainability*. https://doi.org/10.1007/s41660-024-00472-w

24. Onawo, C. E. O., Nwauzoma, U. M., Kawino, D. A., & Onyeaka, H. (2024). Closing the loop: A framework for tackling single-use plastic waste in the food and beverage industry through circular economy—a review. *Journal of Environmental Management, 359*, 120816.

25. OECD. (2023). *New aspects of extended producer responsibility: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle*. OECD Environment Working Papers. https://doi.org/10.1787/cfdc1bdc-en

26. Norton, V., Oloyede, O. O., Lignou, S., Wang, Q. J., Vásquez, G., & Alexi, N. (2023). Understanding consumers' sustainability knowledge and behaviour towards food packaging to develop tailored consumer-centric engagement campaigns: A Greece and the United Kingdom perspective. *Journal of Cleaner Production, 408*, 137169. https://doi.org/10.1016/j.jclepro.2023.137169

27. Batool, F., Kurniawan, T. A., Mohyuddin, A., Othman, M. H. D., Aziz, F., Al-Hazmi, H. E., Goh, H. H., & Anouzla, A. (2024). Environmental impacts of food waste management technologies: A critical review of life cycle assessment studies. *Trends in Food Science & Technology, 143*, 104287. https://doi.org/10.1016/j.tifs.2023.104287

28. Mladenovic, M., van Trijp, H., & Piqueras-Fiszman, B. (2024). Is more merrier? Consumers' inferred value of sustainable aspects for plastic food packaging.

29. Taillie, L. S., et al. (2024). Consumer responses and perceptions related to food packaging and sustainability. *PLOS ONE, 19*(6), e0306123.

30. Sundqvist, J., & Åkerman, M. (2024). Packaging reduction and circularity in food supply systems. *Journal of Cleaner Production, 434*, 140296.

31. Jiménez Romanillos, P., et al. (2024). Consumer and packaging-related research in sustainable food packaging. *Packaging Technology and Science*. https://doi.org/10.1002/pts.2825

32. Htun, K. K., et al. (2023). Smart and intelligent food packaging applications. *Packaging Technology and Science*. https://doi.org/10.1002/pts.2731

33. Duarte, A., et al. (2024). Consumer perceptions and sustainable packaging choices. *Sustainable Futures, 7*, 100193.

34. Boz, Z., Korhonen, V., & Sand, C. K. (2020). Consumer considerations for the implementation of sustainable packaging: A review. *Sustainability, 12*(6), 2192.

35. Rhein, S., & Schmid, M. (2020). Consumers' awareness of plastic packaging and sustainable alternatives. *Resources, Conservation and Recycling, 162*, 105063.

36. Accorsi, R., et al. (2020). Packaging design and sustainability in food supply chains. *Sustainable Production and Consumption, 24*, 48–61.

37. Ncube, L. K., Ude, A. U., Ogunmuyiwa, E. N., Zulkifli, R., & Beas, I. N. (2020). Environmental impact of food packaging materials: A review of contemporary development from conventional plastics to polylactic acid based materials. *Materials, 13*, 4994.

38. Mohammad Fazle Rabbi, M., & Mohammad Bin Amin, M. (2024). Circular economy approaches and sustainable food packaging.

39. Edirisinghe, S., et al. (2024). Circular approaches to sustainable packaging materials.

40. Arijeniwa, A., et al. (2024). Circular economy strategies for food and beverage packaging. *Journal of Environmental Management, 359*, 120816.

41. Pedersen, S., et al. (2024). Consumer and sustainability dimensions of circular packaging. *Frontiers in Sustainability*.

42. Smith, L., et al. (2024). Sustainability labels and consumer decision-making in food packaging.

43. Paliwoda, A., et al. (2024). Sustainability certification, consumer trust and food purchasing behaviour.

44. Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & AbdulGhani, A. (2022). Sustainability of biodegradable plastics: New problem or solution to solve the global plastic pollution? *Current Research in Green and Sustainable Chemistry, 5*, 100273.

45. Testa, F., et al. (2020). Sustainable packaging and consumer perception.

46. Herbes, C., Beuthner, C., & Ramme, I. (2020). Consumer attitudes towards biobased packaging. *Journal of Cleaner Production*.

47. Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & Ujang, Z. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production, 76*, 106–115.

48. Van Ewijk, S., & Stegemann, J. A. (2016). Limitations of the waste hierarchy for achieving absolute reductions in material throughput. *Journal of Cleaner Production, 132*, 122–128.

49. Knauf, M. (2015). Capturing the bioeconomy: The need for a circular economy perspective. *Journal of Cleaner Production*.

50. Jiménez-Guerrero, J., et al. (2024). Environmental evaluation of reusable packaging systems.

51. Martins, M. A., et al. (2024). Life-cycle assessment of reusable plastic containers throughout the fruit and vegetables supply chain. *IFAC-PapersOnLine, 58*(19), 451–456. https://doi.org/10.1016/j.ifacol.2024.09.253

52. Mielinger, E., & Weinrich, R. (2024). An extended deposit refund system on plastic food packaging in Germany: A way to promote the circular economy? Working paper.

53. Meyersohn, M. (2024). Plastic packaging waste management: A case in implementation of extended producer responsibility policies in Minnesota. *Journal of Science Policy & Governance, 24*(1). https://doi.org/10.38126/jspg240110

54. Abatan, N. A., Lottu, A., Ugwuanyi, D., Jacks, S., Oluwademilade, E., Ifesinachi, A., & Obaigbena, A. (2024). Sustainable packaging innovations and their impact on HSE practices in the FMCG industry. *Magna Scientia Advanced Research and Reviews, 10*(1), 379–391. https://doi.org/10.30574/msarr.2024.10.1.0029

55. D'Aniello, A., Donato, C., & Stagno, E. (2025). Packaging the future: A research agenda to unveil consumer trends in sustainable food and beverage choices. *Business Strategy and the Environment, 34*(7), 8779–8831. https://doi.org/10.1002/bse.70037

56. de Oliveira, M. M., Lago, A., Pinto, N. G. M., Araújo, C. O., et al. (2025). Systematic review of innovations in food packaging with a focus on circularity and the reduction of food loss and waste. *Discover Applied Sciences, 7*, 1133. https://doi.org/10.1007/s42452-025-07788-3

57. Espinoza-Orias, N., & Lundquist, L. (2025). Life cycle assessment of reusable food and beverage packaging systems: A proposal of good practice. *Journal of Cleaner Production, 499*, 145207.

58. Du Rietz, S., & Kremel, A. (2024). Consumer behavior as a challenge and opportunity for circular food packaging. *Circular Economy and Sustainability, 4*, 413–438.

59. Corona, B., Tunn, V. S. C., & van den Broek, K. L. (2024). Integrating consumer behaviour into the environmental assessment of circular packaging. *The International Journal of Life Cycle Assessment, 29*, 80–98.

60. Hemachandra, S., Hadjikakou, M., & Pettigrew, S. (2024). A scoping review of food packaging life cycle assessments that account for packaging-related food waste. *The International Journal of Life Cycle Assessment, 29*, 1899–1915.

61. Stevens, A. S., et al. (2024). Plastic food packaging from five countries contains endocrine- and metabolism-disrupting chemicals. *Environmental Science & Technology*.

62. Pearson, A. J., Mukherjee, K., Fattori, V., et al. (2024). Opportunities and challenges for global food safety in advancing circular policies and practices in agrifood systems. *npj Science of Food, 8*, 60.

63. Van der Fels-Klerx, H. J., van Asselt, E. D., Berendsen, B., et al. (2024). Framework for evaluation of food safety in the circular food system. *npj Science of Food, 8*, 36.

64. FAO. (2024). *Ensuring food safety in a circular economy*. Food and Agriculture Organization of the United Nations.

65. Food Safety and Standards Authority of India (FSSAI). (2018). *Food Safety and Standards (Packaging) Regulations, 2018*. Government of India.

66. OECD. (2023). *New aspects of extended producer responsibility: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle*. OECD Publishing.

67. Ramasubramanian, B., Tan, J., Chellappan, V., & Ramakrishna, S. (2023). Recent advances in extended producer responsibility initiatives for plastic waste management in Germany and UK.

68. Ezeudu, O. B. (2024). Harnessing the drivers and barriers to implementation of extended producer responsibility for circular economy in Nigeria.

69. Flygansvær, B., & Dahlstrom, R. (2024). Enhancing circular supply chains via ecological packaging.

70. Dey, A., & Ashok, S. D. (2024). Fuzzy logic based qualitative indicators for promoting extended producer responsibility and sustainable food packaging waste management.

71. Poonia, V., Sangwan, K. S., Kulshrestha, R., & Shah, J. D. (2024). Overcoming the extended producer responsibility challenges of packaging material through integrated refurbishing and recycling.

72. Onawo, C. E. O., Nwauzoma, U. M., Kawino, D. A., & Onyeaka, H. (2024). Closing the loop: A framework for tackling single-use plastic waste in the food and beverage industry through circular economy.

73. Gupta, P., et al. (2024). Migration of chemical compounds from packaging materials into packaged foods.

74. Gündoğdu, S., et al. (2024). Chemical and microplastic risks associated with plastic food packaging.

75. Deeney, M., et al. (2023). Human health effects of recycling and reusing food-sector consumer plastics.

76. Kirchherr, J., et al. (2023). Conceptualizing the circular economy revisited.

77. Balachandran, G., & Chaturvedi, P. (2025). Food Quality, Safety and Sustainability – A Critical Review of Factors Influencing Consumer Viewpoint and Practices. *Journal of Informatics Education and Research, 5*(4). https://doi.org/10.52783/jier.v5i4.3711

78. Norton, V., et al. (2023). Understanding consumers' sustainability knowledge and behaviour towards food packaging.

79. Ada, E., et al. (2023). Identifying the drivers of circular food packaging.

80. Hussain, S., Akhter, R., & Maktedar, S. S. (2024). Advancements in sustainable food packaging.

81. Yadav, P., et al. (2024). Life cycle assessment of reusable plastic food packaging.

82. Batool, F., et al. (2024). Environmental impacts of food waste management technologies.

83. Sundqvist, J., & Åkerman, M. (2024). Circular packaging and packaging reduction.

84. Taillie, L. S., et al. (2024). Consumer responses to sustainable packaging.

85. Duarte, A., et al. (2024). Sustainable packaging and consumer behaviour.

86. Jiménez Romanillos, P., et al. (2024). Packaging sustainability and consumer response.

87. Htun, K. K., et al. (2023). Smart packaging and consumer information.

88. Boz, Z., Korhonen, V., & Sand, C. K. (2020). Consumer considerations for sustainable packaging.

89. Rhein, S., & Schmid, M. (2020). Consumer awareness of plastic packaging.

90. Ncube, L. K., et al. (2020). Environmental impact of food packaging materials.

91. Martínez-Sánchez, L., et al. (2023). Sustainable food packaging: An updated definition following a holistic approach.